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FLIGHT PERIODICITY IN COLORADO BITING MIDGES (DIPTERA: CERATOPOGONIDAE)[1,2]

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With the possible exception of some species of *Forcipomyia,* which act as pollinators of cacao (Billies, 1941), biting midges (Diptera: Ceratopogonidae) in the genera *Atrichopogon, Bezzia, Dasyhelea, Forcipomyia,* and *Palpomyia* have little if any striking economic importance compared with pestiferous bloodsucking species (Wirth, 1956; Chan and LeRoux, 1967). As a consequence we know much less of the basic biology and ecology of species in these genera than we do for *Culicoides* and *Leptoconops*. Economic importance, however, is not an absolute prerequisite for study. The diversity of adult feeding behavior within the Ceratopogonidae, for example, poses an array of behavioral and biological problems which continue to challenge contemporary observers of insect natural history (Wirth, 1956; Downes, 1978).

In northeastern Colorado, virtually nothing is known about the flight habits of adult Ceratopogonidae. Consequently, I undertook this study to make observations of seasonal abundance and diel patterns of flight activity for *Atrichopogon fusculus* (Coq.), *Bezzia pulverea* (Coq.), *B. setulosa* (Loew), *Dasyhelea grisea* (Coq.), *D. mutabilis* (Coq.), *Forcipomyia bipunctata* (L.), *F. brevipennis* (Macquart), and *Palpomyia tibialis* (Meigen). In this paper are reported the results of this study.

Materials and Methods

The flight activity of airborne Ceratopogonidae was assessed between January and December 1978 by identifying and counting those collected with a vehicle-mounted interception trap (Barnard, 1979). Throughout this period collections were made once every 14 days and each time specimens were collected over a 24-hr period. Diel flight activity was related to important temporal events, using times of sunrise and sunset as reference points. Each day of collection was divided into 20 periods: period one began at morning nautical twilight and ended at sunrise; periods 2–11 were derived by dividing the time between sunrise and sunset into 10 equal parts; period 12 began at sunset and ended at the end of evening nautical twilight; the time from the end of evening nautical twilight to the beginning of morning nautical twilight was divided into 8 equal parts and formed periods 13–20. During the year, periods one and 12 ranged from 59 to 74 min. Four collection runs were made during each of these 2 periods: one at the beginning of the period, one at 22 ± 5 min, one at 45 ± 5 min, and one at the end of the period. I made 3 collection runs, equally spaced in time during each of periods 2–11 and 13–20. A mean value for flight activity was calculated for each period by summing the number of individuals collected in each run in a given period and dividing by the number of runs for that period.

Throughout this study, each collection run was made over the same course on a lightly travelled, graded-surface road 0.25 km west of Wattenburg, Colorado (104°50′W, 40°01′N) in the South Platte River drainage system. The course passed through partially flooded, low-lying areas and higher irrigated pastures on which horses and cattle grazed. Two drylot dairies and 1 drylot sheep operation were located, respectively, 500 and 1000 m south, and 1500 m west of the course. On each collection run I travelled the course in one direction (2.0 km) and then returned to the starting point, a total distance of 4.0 km. Runs were made at ca. 40 km/hr and lasted ca. 7 min. During all dusk to dawn periods I made collection runs with only parking lights on. Specimens collected during each run were stored separately and temporarily (in the collection bag used for that run) in an ice chest over dry ice.

Results

Data from observations of seasonal activity and diel patterns of flight for each species of biting midge collected during this study are given in Table 1.

Atrichopogon

Seasonal flight activity of male and female *A. fusculus* commenced in May and airborne females were most abundant in July. Population levels of males diminished in June, but increased and remained high thereafter until October. *A. fusculus* exhibited peak diel flight activity during periods 11 and 12, before or after sunset, and during periods 1 and 2 before and after sunrise.

Forcipomyia

Forcipomyia bipunctata was active from April to October, population levels of both sexes were highest in July. *F. brevipennis* commenced flight activity in June and terminated activity in mid-November. Population levels for females were high from July to September, whereas males were most abundant in September. Few males or females of *F. bipunctata* or *F. brevipennis* were collected after September.

The diel flight period in *F. bipunctata* was bimodal from July to September with the main peak at sunset and a smaller peak near sunrise. Adults

Table 1. Mean number of airborne adult Ceratopogonidae collected in each period in each month, and the percentage of total numbers of adults collected in periods 1, 2, 11, and 12, and the mean percentage of total adults collected in periods 3 thru 10 and 13 thru 20. Wattenburg, Colorado, 1978. (SR = sunrise, SS = sunset, PH = photophase, SC = scotophase)

		Period					
				PH			SC
Month	Sex	1—SR—2		3–10	11—SS—12		13–20
Atrichopogon fusculus							
May	M	0	0	1.4	3.2	4.5	0.2
	F	0	0	1.2	1.3	4.0	0
June	M	0	0	0	0	0	0.2
	F	0	1.3	1.1	3.5	3.2	1.4
July	M	2.9	1.4	0	5.6	0	0.2
	F	4.4	1.8	0	14.1	19.9	1.1
August	M	0	2.2	0	3.3	3.3	0
	F	0	3.1	0.2	7.1	4.0	1.1
September	M	0	1.3	0	12.9	1.6	0
	F	0	0	0	7.1	1.3	1.1
October	M	0	0	1.1	1.3	0	1.1
	F	0	0	0.2	1.3	1.3	0.2
% of total	M	6.2	10.2	5.2	55.1	19.7	3.6
	F	5.1	7.2	3.2	39.9	39.0	5.6
Forcipomyia bipunctata							
April	M	0	0	0.3	0	0	0
	F	0	0	1.4	0	0	0
May	M	1.4	0	0	1.5	1.4	0
	F	0	0	1.3	2.5	4.5	1.2
June	M	0	0	2.8	0	0	0
	F	0	0	1.2	5.6	2.2	1.1
July	M	1.3	1.4	0.1	3.5	4.0	1.7
	F	3.5	2.5	0.2	25.1	50.1	4.3
August	M	0	1.6	0.1	3.2	4.0	1.3
	F	0	2.5	0.2	5.0	6.3	1.4
September	M	0	0	0	1.3	3.3	0.3
	F	0	2.5	1.2	1.8	5.6	1.3
October	M	0	0	0.2	0	1.2	0
	F	0	0	1.2	1.3	1.8	0
% of total	M	7.5	8.4	9.7	26.5	38.7	9.2
	F	2.5	5.4	4.8	29.8	50.8	6.7
Forcipomyia brevipennis							
June	M	0	0	1.6	4.5	1.8	0
	F	0	1.2	1.3	0	0	0

Table 1. Continued

		Period					
				PH			SC
Month	Sex	1—SR—2		3–10	11—SS—12		13–20
July	M	0	0	0	6.3	4.9	1.3
	F	0	0	0.3	4.5	2.5	1.3
August	M	0	0	0.2	3.2	2.2	0.5
	F	0	0	0.1	2.2	4.9	1.1
September	M	0	0	0	35.5	3.5	0
	F	0	0	0.1	14.1	9.8	0
October	M	0	0	0.1	2.8	0	0
	F	0	0	0.2	0	1.8	0
November	M	0	0	0	2.3	0	0
% of total	M	0	0	2.7	77.2	17.5	2.6
	F	0	2.6	4.4	45.8	41.9	5.3
Dasyhelea grisea							
April	F	0	0	0.2	0	0	0
May	M	0	0	0.2	0	0	0
	F	0	1.2	1.8	1.6	0.5	0
June	M	0	1.2	1.2	0	0	0
	F	0	3.1	1.8	1.8	0	0
July	M	0	10.2	3.1	6.3	1.8	0
	F	2.2	31.6	6.2	56.2	39.8	0
August	M	2.8	3.2	4.3	19.9	0	0
	F	2.5	7.9	4.7	63.1	12.6	0
September	M	0	1.8	1.4	89.1	31.6	0
	F	0	5.9	3.1	501.2	158.5	0
October	M	0	0	1.1	0	0	0
	F	0	0	3.5	31.6	0	0
% of total	M	1.5	9.2	6.3	64.4	18.6	0
	F	0.4	5.3	2.3	69.6	22.4	0
Dasyhelea mutabilis							
April	M	0	0	2.9	0	0	0
	F	0	0	1.9	0	0	0
May	M	0	0	12.2	4.0	1.3	0
	F	0	3.2	36.5	31.6	9	0
June	M	0	1.3	81.7	1.6	0	0
	F	0	3.1	365.2	15.8	1.3	0
July	M	5.0	31.6	54.6	79.4	9.9	0
	F	3.9	125.8	158.4	147.3	141.3	0
August	M	3.9	7.9	29.8	75.8	38.0	0
	F	1.4	10.4	74.9	141.2	103.1	0

Table 1. Continued

Month	Sex	Period					
				PH			SC
		1—SR—2		3–10	11—SS—12		13–20
September	M	0	2.9	35.5	1258.9	2.8	0
	F	0	7.6	122.3	757.6	288.3	0
October	M	0	0	8.7	3.2	0	0
	F	0	0	105.9	125.9	3.2	0
November	F	0	0	0.5	1.1	0	0
% of total	M	0.5	2.5	12.9	81.1	3.0	0
	F	.2	5.4	31.1	43.8	19.6	0
Palpomyia tibialis							
May	F	0	0	0	1.4	10.0	0
June	M	0	0	0	0	1.6	0
	F	0	0	.2	2.5	34.6	1.3
July	F	0	0	0	0	9.7	0.9
% of total	M	0	0	0	0	100	0
	F	0	0	.3	6.4	89.7	3.6
Bezzia pulverea							
May	M	0	0	0	0	1.3	0
	F	0	0	0	2.2	9.7	0
June	M	0	0	3.0	7.0	8.2	.4
	F	2.5	35.4	6.4	37.9	53.7	5.5
July	M	0	0	0	3.3	1.6	0
	F	0	0	0	7.1	0	.6
August	F	0	3.6	0	0	2.1	.3
September	F	0	0	0	1.6	0	0
% of total	M	0	0	12.1	41.5	44.8	1.6
	F	1.5	23.1	3.8	28.9	38.9	3.8
Bezzia setulosa							
May	M	0	0	0	1.6	2.0	0
	F	0	0	0	1.8	12.7	0
June	M	0	0	.2	7.1	1.8	0
	F	0	2.5	.8	15.8	17.8	2.2
July	M	0	0	0	13.9	1.3	0.2
	F	1.8	0	0	28.8	24.5	1.4
August	M	0	31.6	1.0	281.8	354.8	5.0
	F	0	97.8	1.2	56.2	292.9	19.9
September	M	0	1.4	0	12.6	1.6	0
	F	0	1.6	0	9.8	2.5	0
October	F	0	0	0	1.4	0	0
% of total	M	0	4.6	0.2	44.1	50.3	0.8
	F	.3	17.2	.3	19.2	59.0	4.0

were active throughout the scotophase in July, and during the early parts of the scotophase in August and September. *F. brevipennis* exhibited a unimodal flight period with peak activity in period 11 (period 12 for females in August). High levels of flight activity took place during the photophase in June and flight during the scotophase was noted in July and August.

Dasyhelea

Dasyhelea grisea was active from April to October, while *D. mutabilis* commenced flight activity in April and ceased activity in November. *D. mutabilis* population levels were highest between June and October, and levels for each sex fluctuated only slightly during this time. *D. grisea* population levels were highest from mid-July to mid-September.

D. grisea showed a bimodal diel flight period from July to September, with the main peak of activity observed before sunset and the second peak after sunrise. In October and April, flight occurred principally in the late afternoon, whereas activity in May and June was greatest during the morning hours. From May to October, flight activity by *D. mutabilis* took place between periods 1 and 12; adults were never collected at night. In April, flight occurred during midday only, and in November, only females were collected, these in periods 10 and 11.

Bezzia

Both sexes of *B. setulosa* were active between May and September; only females were collected in November. Overall *B. setulosa* population levels were highest in August, and except for this month and September, when males were most abundant, females dominated collections. *B. pulverea* was active between May and September. Males and females were most abundant in June, after which population levels decreased; males were not collected after August.

Between May and November, both sexes of *B. setulosa* were active in periods 11, 12, or both (before and after sunset) but a preference was shown for neither period. Activity diminished in period 13, and periods 14–20 and period 1 (before sunrise) were devoid of flight activity in all months except July. In July, *B. setulosa* females were active sporadically throughout the scotophase. In August and September, males and females were active in the morning during period 2 (following sunrise) and in June flight activity by females continued into period 4 (ending at 1000). *Bezzia setulosa* was generally inactive during the daytime hours.

In June, *B. pulverea* was active throughout the photophase but activity by both sexes peaked in period 12 (after sunset) and by females again in period 2 (following sunrise). Also in June, flight continued into period 15 (ending at 2405) and commenced again during the morning crepuscule (period 1). The principal flight time between July and September was period 11 (before sunset) as was period 12 in May, although activity by females extended into period 16 in July. Male *B. pulverea* were not collected after July.

Palpomyia

P. tibialis was active between May and July; female population levels peaked in June, the only month in which males were collected.

P. tibialis exhibited a unimodal diel flight period. Females were active principally during the evening crepuscule between May and July, but in June and July flight continued for several hours into the scotophase. Females were also active during period 11 (before sunset) in May and June and during period 9 in June. Male *P. tibialis* were collected only during period 12 in June.

Discussion

The diel flight period in biting midges collected during this study was seasonally variable. Flight periods observed in April, October, and November, for example, appeared to be temperature-mediated; temperatures in these months regularly fall to below 5°C during the mid-late scotophase and early photophase (Barnard, unpubl. data). In contrast, flight periods observed in July and August when air temperatures were ≥10°C, presumably are those expressed in the absence of flight-inhibiting low temperatures. Such seasonally-influenced flight periods are best illustrated by flight activity data for *A. fusculus, F. bipunctata,* and *D. grisea* (and to a lesser extent, *D. mutabilis*). In these species, a secondary peak of flight activity at sunrise was not observed until July. Moreover, in these species diurnal flight activity during the summer is displaced toward either end of the photophase, in an apparent response to increasing daytime temperatures.

The influence of season on flight period is less apparent for other species. In *F. brevipennis,* for example, flight does not extend into the scotophase until July and August. *Bezzia setulosa* exhibits a unimodal flight period in May and October, a bimodal flight period in August and September, and a unimodal period for males and bimodal period for females in June and July.

Flight activity in *P. tibialis* and *B. pulverea* was of too little duration and concentrated in one month to be affected by season (64 and 83%, respectively, of all *P. tibialis* and *B. pulverea* were collected in June).

I characterized diel flight during periods of biting midges collected during this study by calculating the percentage of total males and females in flight in each of periods 1, 2, 11, and 12; and for periods 3 thru 10 and 13 thru 20, by calculating the mean percentage of total males and females in flight per period. The percentages thus calculated are weighted in favor of months in which flight activity was most concentrated; however, it is in these months that conditions for flight are most favorable and the flight activity observed free from the inhibiting effect of low temperature. Each of the biting midge species collected was active principally during the late afternoon and evening crepuscule. *Atrichopogon fusculus* males, females of *F. bipunctata* and *B. pulverea,* and males and females of *D. grisea* and *B. setulosa,* in addition, showed a morning-crepuscular flight peak of lower amplitude than the evening peak. Males and females of each species except male *P. tibialis* (which were collected only during period 12) were active during the daytime and all species except male *P. tibialis, D. grisea,* and *D. mutabilis* were active at night. Consistent with their flower-seeking food habits, *Dasyhelea* species, particularly female *D. mutabilis* were active primarily during daylight hours.

Kaufmann (1974) described the diel flight period of *Forcipomyia inornatipennis* (Austen), a cacao pollinator in Ghana, as bimodal with peak activity at dawn and dusk. And because of their biological diversity and in some cases economic importance (Bystrak and Wirth, 1978), other *Forcipomyia* species have been studied in detail. Hematophagous species suck blood from various insects and from phalangids (Wirth, 1956; Wirth and Stone, 1973), whereas species in the subgenus *Euprojoannisia* are important pollinators of cacao (Billies, 1941; Saunders, 1924; Bystrak and Wirth, 1978) and Pará rubber (Wirth, 1956).

Little is known about the feeding habits of species in the remaining genera. Some species of *Atrichopogon* (e.g., *A. epicautae* Wirth, *A. farri* Wirth, *A. meloesugans* Kieffer, and *A. oedemararum* Stora) suck the blood of oedemerid and meloid beetles (Downes, 1955; Wirth and Stone, 1973; Wirth, 1956). Other species, such as *A. pollinivorus* Downes and *A. pavidus* (Winnertz), fly to flowers and feed solely upon nectar and pollen (Downes, 1955). In *Bezzia* and *Palpomyia,* flight at dawn and dusk apparently serves at least 2 functions: meeting of the sexes and procurement of food (Downes, 1978). Downes (1978) observed flight activity by *B. setulosa* in late afternoon and noted several instances of this species preying upon male chironomid midges and one instance of *B. setulosa* feeding upon *B. setulosa.* He also noted that *Palpomyia* and *Bezzia* spp. feed upon chaoborids, chironomids (Diptera), and upon baetids (Ephemeroptera), each of which as a taxon was most active in this study in periods 10–12, the same time *P. tibialis, B. setulosa,* and *B. pulverea* adults were most active.

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Footnotes

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[2] This paper reports the results of research only. Mention of a proprietary product does not constitute a recommendation or an endorsement by the USDA.